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Fabrication and Characterization of Amorphous In-Si-O Thin Films via Solution Process

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Since the report on novel properties of amorphous In-Ga-Zn-O (IGZO) system [1], doped indium oxides have been intensively studied as channel materials of thin-film transistors for high-definition flat panel displays. Despite their high performance, improvement of the robustness against external stress is still one of the most important issues. Among other elements, Si-doping is effective to stabilize the amorphous structure and reduce the oxide deficiency [2-4]. Solution processing for fabricating thin films has several advantages with regard to roll-to-roll compatibility, efficient use of materials, and the ability to operate at atmospheric pressure. However, solution processing of In-Si-O thin film with high quality has not been reported thus far.

Here, we report the characteristics of an amorphous oxide semiconductor In-Si-O films fabricated via spin coating solution processing. The films were characterized via thermal desorption spectroscopy (TDS) which suggests that organic residues, such as organic functional groups from raw materials and solvents, were almost completely desorbed from the films at approximately 400 °C (Fig1). Based on the x-ray diffraction (XRD), we confirmed that pure In_2O_3 film crystalizes at approximately 350 °C and that the crystallization temperature increases with the silicon concentration (Fig2). Synchrotron radiation extended x-ray absorption fine structure (EXAFS) also shows that suppression of In-O network ordering in In_2O_3 films annealed at low temperatures. The In-Si-O films with silicon concentrations of over 3 % exhibit high electrical resistances, indicating that films fabricated via spin coating contain few oxygen vacancies.

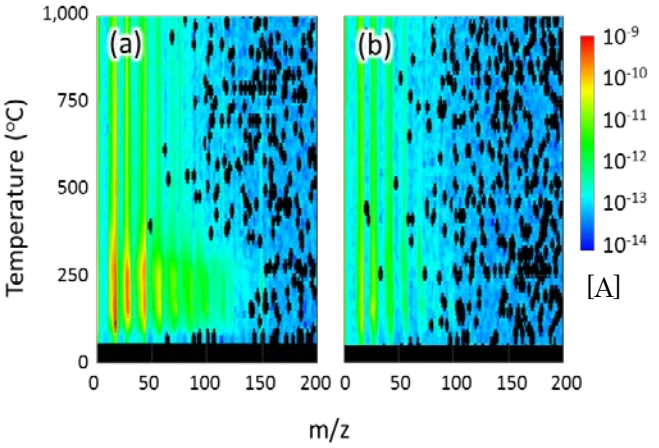

Fig 1: TDS characteristics of (a) 0 at% Si (InO_x), and (b) 100% Si (SiO_x) films. The color bar shows the desorption intensity in arbitrary units.

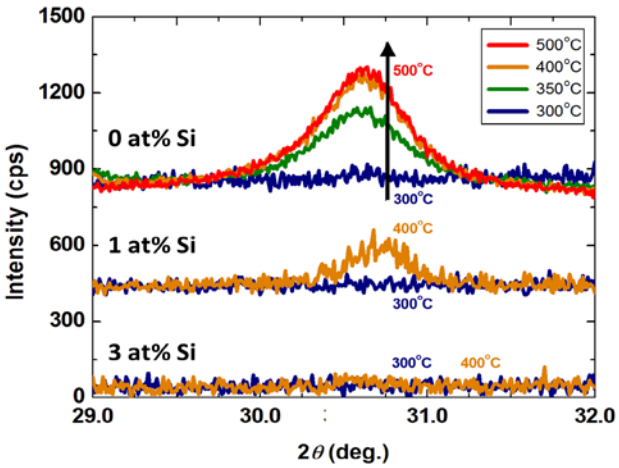

Fig 2: XRD profiles of films that were spin-coated 8 times. The silicon concentration and annealing temperature are shown in the figure. Profiles are vertically offset for clarity.

In this study, spin coating solution process has adapted to fabricate the thin films transistors (TFTs) with high quality. Various silicon concentration with different annealing temperatures was performed to conform the amorphous structures stabilization and crystallization temperatures based on the XRD of In_2O_3 222 reflection peak. Wide range of silicon concentration (0 at.%, 1 at.%, 3 at.%, 5 at.%, 9 at.%, and 50 at.%) have proved that with the phase diagram of amorphous structures stabilities under different annealing temperatures (Fig3). Crystallization occurs above 350℃ in the InO_x film, and the crystallization temperature increases with silicon concentration. Stabilization of the In-O has been proved by silicon doping ≥1% up to high annealing temperature (T_a=1000℃). In another word, increase the silicon concentration help the structure to stabilize as amorphous to a certain high T_a. Amorphous In-Si-O fabricated with low annealing temperature and low silicon concentration conformed that high quality TFTs.

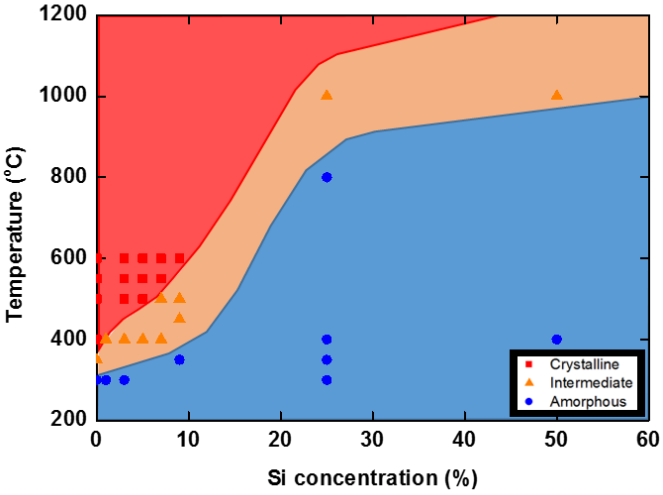

Fig 3: XRD for the In-Si-O with various Silicon concentration (0 at.% Si, 1 at.% Si, 3 at.% Si, 5 at.% Si, 7 at.% Si, 9 at.% Si, 25 at.% Si, and 50 at.% Si) and various T_as (from 300℃ to 1000℃). Blue color region shows the amorphous phase, orange color region shows the intermediate structure phase, and red color region shows the crystal structure phase.

Our results suggest that these In-Si-O thin films fabricated via spin coating solution processing have significant potential for use as channels in field effect transistors designed for next-generation flat panel displays.

References

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